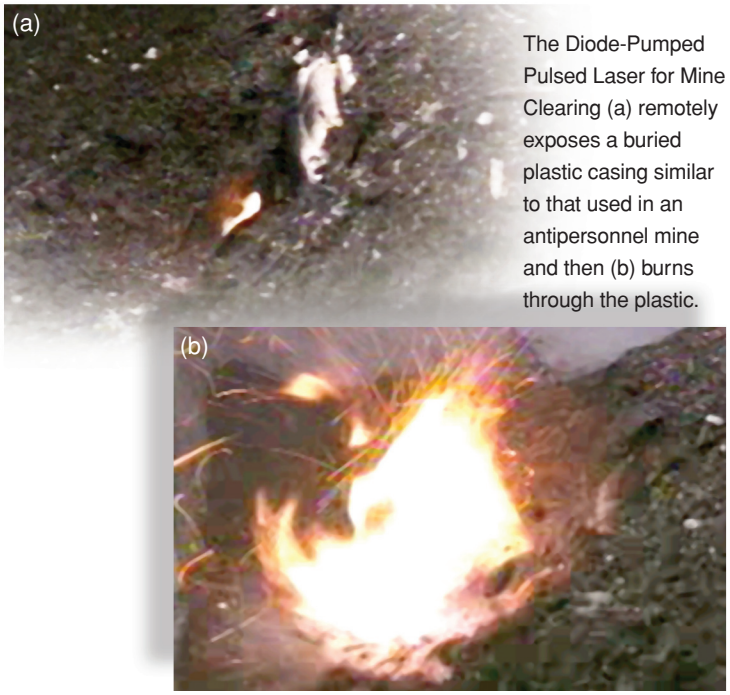
Laser Burrows into the Earth to Destroy Land Mines

ONE of the great scourges of warfare is the land mine. Although an effective battlefield weapon, land mines kill or maim nearly 45,000 civilians (including 20,000 children) worldwide every year. According to the United Nations, more than 110 million antipersonnel and antitank mines have been planted in more than 70 countries. About 100,000 mines are cleared annually, mainly by humanitarian agencies, but military forces lay another 2 million each year.

Current methods to clear mines, called demining, are slow and cumbersome. Some methods, such as dragging a plow across the ground, risk damaging equipment and injuring people. Demining can also be deadly; one deminer dies for every 5,000 mines neutralized. Many nations, the U.S. Army, and humanitarian relief agencies have searched for less dangerous technologies.

Deminers will soon have a better approach: a compact tool that rapidly uncovers and neutralizes land mines from a safe distance by using extremely powerful pulses of laser light. Developed by a team of Livermore physicists and engineers, the Diode-Pumped Pulsed Laser for Mine Clearing (DP-PLMC) won a 2004 R&D 100 Award for its promise of revolutionizing the practice of demining.



The Diode-Pumped Pulsed Laser for Mine Clearing (a) remotely exposes a buried plastic casing similar to that used in an antipersonnel mine and then (b) burns through the plastic.

World's Most Powerful Diode-Pumped Laser

The solid-state DP-PLMC produces high-average-power laser bursts of 25,000 watts of light, making it the world's most powerful diode-pumped laser. The pulse repetition rate is 200 per second, with each pulse producing a peak power of up to 250,000 watts. This pulsed power technology permits the laser beam to burrow into the ground, expose the mine, and then burn it up (a process called deflagration) instead of exploding it.

The laser is a result of work done for the U.S. Army's Space and Missile Defense Command to produce a system that can be used for short-range, tactical defense. The research team found that the laser could penetrate soil at a rate of 40 centimeters per second and, hence, could potentially neutralize buried land mines. With such a quick tunneling rate, the laser also eliminates the chronic problem of false positives, which can significantly slow down the demining process. The current 30-kilowatt prototype version of the laser has demonstrated the technology's key elements and will enable a full-power mobile version to be built within the next two years. Livermore physicist Mark Rotter, who led the development team, says, "By adding a mine detection capability, such as ground-penetrating synthetic-aperture radar, to the laser platform, we can deploy a truly versatile land-mine neutralization system."

The laser builds on the success of Livermore's solid-state heat capacity laser (SSHCL), which won a 2002 R&D 100 Award. (See *S&TR*, October 2002, pp. 8–9.) In the SSHCL, high-average-power bursts are made possible by separating the cooling cycle from the laser's amplifier pumping cycle. As a result, the maximum average power is increased from 5,000 watts to more than 25,000 watts.

Two upgrades to the SSHCL permitted the development of the DP-PLMC. First, the laser's flashlamps, which were used to pump the amplifiers, were replaced by arrays of high-power laser diodes for much greater efficiency. During the past decade, Livermore scientists have pioneered the use of high-average-power diode arrays in lasers to sharply reduce power and space requirements. The second upgrade was to replace the neodymium-doped glass with crystalline neodymium-doped garnet for higher mechanical strength and more rapid cooling, producing a faster turnaround time between laser firings. The two upgrades made possible a compact, efficient laser demining system that can be deployed on a wheeled or tracked vehicle.

Fulfilling the Solid-State Promise

Many demining experts had hoped that mobile, solid-state laser systems could fulfill the promise of the laser to remotely and

efficiently neutralize land mines. Solid-state lasers do not require the toxic and corrosive fuels used by chemical lasers, and electrical power is efficiently converted to a high-power beam without producing waste effluents. Although solid-state laser demining systems are commercially available, those systems use a small (several-hundred-watt), continuous output laser. Because that laser has a low power output, unexploded mines must be directly visible to the laser beam. Any sand or soil covering the buried mine prevents it from reaching the temperatures that initiate burning.

In contrast, the extremely powerful, pulsed laser beam from the DP-PLMC requires no human interaction to expose the mine. The beam digs through soil by explosively vaporizing it to remotely reveal underlying mines. Once the laser beam encounters a mine, it quickly penetrates the plastic outer casing of antipersonnel mines or the metal casing of antitank mines. After the laser penetrates the case, its power level is reduced so the mine is neutralized by deflagration rather than detonation.

"We knew that once we demonstrated the laser's capacity to dig into the ground and expose a mine, we had the potential to dramatically alter demining technology," says Rotter. Because the DP-PLMC does not require personnel to manually uncover the land mine, the system dramatically reduces the chance of injury. Based on the output power of the laser, a maximum standoff distance of 1 kilometer can be achieved. Such a distance can be obtained, in principle, by placing the laser on an elevated site or raising the output beam by means of periscope mirrors so as to overlook the mine field without obstruction. In general, mine detection and neutralization would occur at distances less than 1 kilometer.

The DP-PLMC is designed to burn up the mine instead of detonating it, although, says Rotter, the system has yet to be tested on a live mine. With deflagration, the laser will not leave a crater in the earth—a characteristic of other neutralization processes. Keeping the environment unscarred is an important advantage for restoring land to productive use.

Just Add Batteries

The current DP-PLMC prototype is powered by lithium–ion batteries. The Livermore team is working with a U.S. company to adapt the system to a vehicle such as a hybrid-electric-powered Humvee. In this configuration, the Humvee's generator and batteries could power both the vehicle and the laser, requiring only diesel fuel to support full operation.

The DP-PLMC is available for commercial license for demining. Major General John M. Urias of the U.S. Army Space and Missile Defense Command indicates the laser could have related applications. In a letter to Rotter, he says, "It is clear to me that you have accomplished a critical step toward the development of a solid-state laser system that will be useful not only in mine-clearing operations, but also for the challenge of the improvised explosive device problem U.S. Forces currently face in Iraq and terrorists' threats that include unknown bomb devices."

The development of the DP-PLMC grew out of Livermore's work for the Army's Space and Missile Defense Command on a solid-state laser for battlefield use. The laser shows promise as the first high-energy laser compact enough to be considered part of the Army's future combat system for short-range (1- to 10-kilometer) air defense against tactical battlefield threats such as rockets, artillery, and mortars. (See *S&TR*, April 2002, pp. 19–21.)

In more ways than one, the DP-PLMC is shedding light on a vexing problem for the U.S. Army and more than 70 nations.

—Arnie Heller

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